Section 1. Description of Subsurface Hydrocarbon Plume

In 1988 the Hawaiian Refinery delineated a hydrocarbon plume underlying the western portion of the Refinery known as the Refinery Backyard. This area covers an area approximately 13 acres in size (refer to Drawing 10-HB-1080 for overhead view). The Refinery has taken positive measures to recover this sub-surface hydrocarbon by installing an oil recovery system. The source of the oil was the oily process sewer pipelines. The oily sewer system was repaired and inspected in 1988 and 1989. See Section 2 of this report. Following sampling and analysis, the sub-surface hydrocarbon was found to be a mixture of FCC fractionator bottoms and lighter fuel oils. The "lighter" composition of this hydrocarbon mixture makes skimming a suitable recovery technique.

Following initial plume delineation, a line of oil recovery and monitoring wells were installed to begin recovery of the sub-surface hydrocarbon and serve as a barrier to prevent possible migration of the oil to the Pacific Ocean.

The Refinery's Backyard Oil Recovery System is comprised of twenty three oil recovery wells (R-14 thru R-33, RW2, RW3 and R-11) fitted with ARO double-diaphragm, pneumatically-operated pumps and associated SOS (Selective Oil Skimmer) units and an oil recovery header. The header ties into tank 5481 for temporary containment and gaging of the recovered oil. The air for driving these ARO pumps is supplied by the Refinery's air supply header.

The typical Backyard oil recovery system utilizes 8 inch, Schedule 40 PVC pipe with a slotted section (0.02" slot width) to allow for infiltration of hydrocarbon. A PVC end cap is glued to a 20 ft. long, non-slotted PVC pipe. Approximately 3.5 ft. from the top is the slotted section that extends downward 6 feet . (See enclosed Sketch 10-083, Fig. 1-Well Casing Dimension , Fig. 2-Typical Well Casing Summary, Fig. 3- Typical Oil Recovery Well Setup and Fig. 4- SOS Skimmer for clarification).

A typical Backyard well casing was installed by first drilling a 24 inch diameter hole approximately 15-20 feet below the ground surface. After the mean water level(5-7 ft. below surface) was determined, a previously assembled casing was set in the hole so the mean water level would intersect the mid-point of the slotted section of the PVC pipe. Clean fill gravel was then added to help anchor the PVC casing assembly and to allow for optimum infiltration of the oil into the slotted section of the well casing. This gravel fill extended slightly above the slotted section, and concrete (1 ft. thick) was added above this gravel fill to the ground surface.

An SOS skimmer is suspended in the well casing with a cable, and the oil pickup float screen is adjusted so the floating hydrocarbon layer is effectively skimmed. An ARO double-diaphragm pump is secured to the top of the well casing and connected to the floating oil skimmer by an oil recovery hose.

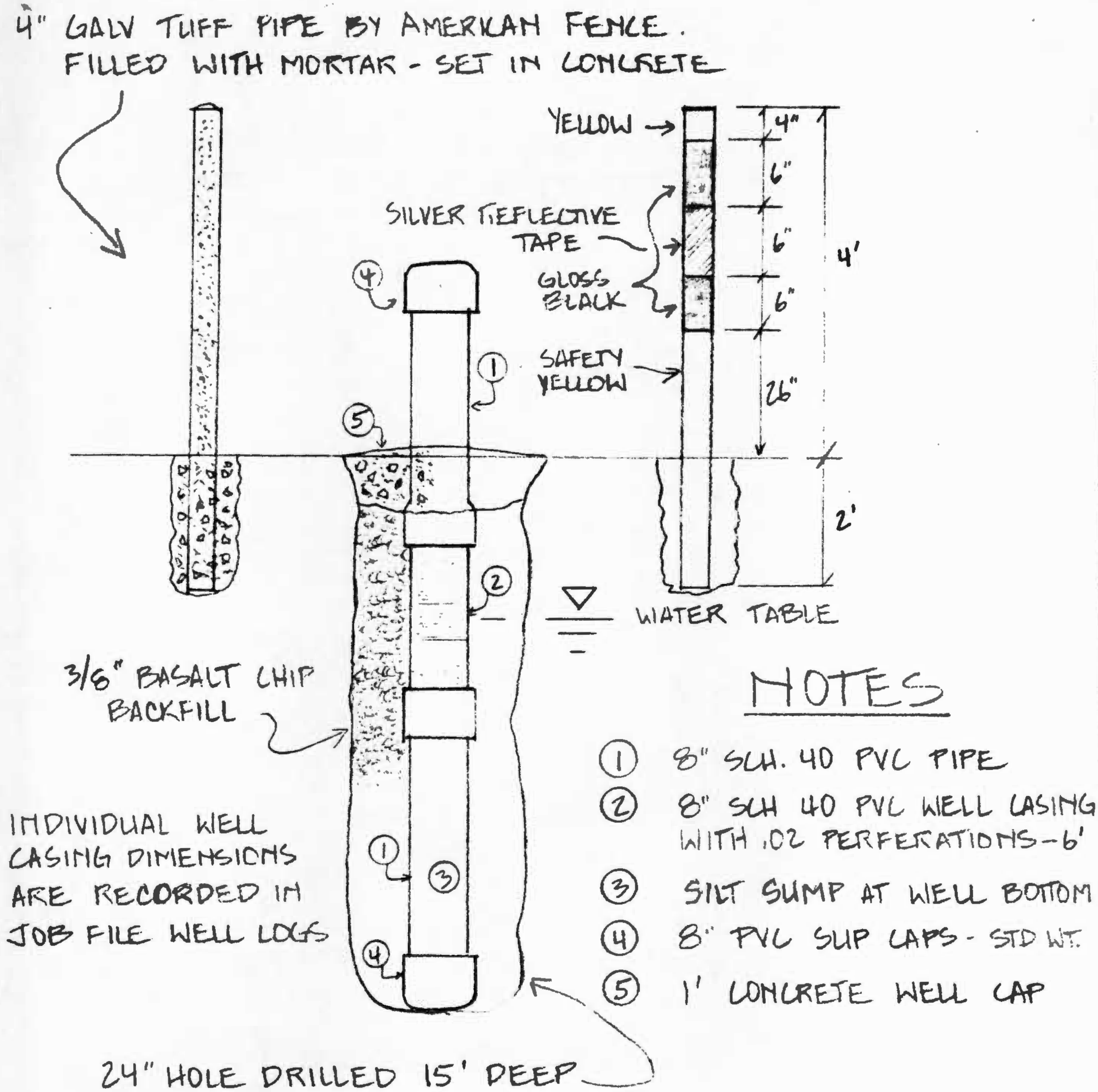
The method of operation is as follows: The system is activated by means of a controller box which introduces air from the Refinery air supply header to one side of the ARO pump diaphragm, which cycles the pump and creates suction. The suction side of the pump is connected to the floating skimmer in the well. Floating hydrocarbon is drawn through the selective oil screen (allows mostly oil to pass through) and pulled up through the oil recovery hose to the other side of the ARO pump. A one-way check valve prevents oil from flowing downwards back to the skimmer. The ARO pump sends the recovered oil into the recovery header where it's routed to tank 5481 (9,000 gallon capacity) for temporary containment and gaging. When tank 5481 fills sufficiently, the oil is pumped to tank 162 where it is proportionately mixed with fresh crude and reprocessed(recycled) through the Crude Unit. Since its installation and activation in 1988, the Backyard Oil Recovery System has recovered approximately 8,000 barrels of hydrocarbon up to December 1991. The Backyard system continues to recover hydrocarbon at the rate of approximately 24 barrels a month.

The next phase of this Backyard Oil Recovery Project is to commission 8 more wells (Well no.s R39, R40, R41, R42, R43, R44, R45, R46) (parallel to Alky & Isomerization Plants) located directly North of the existing line of wells. The well casings have already been installed. We are currently drafting an EWO (Engineering Work Order) to design a header system and its hookup, along with installation of another control box for this new array of wells.

Following commissioning of these 8 new oil recovery wells, we plan to address the second tier of wells (R-34, R-35, R-38 and R-4) between the operating wells and the ocean. We plan to pump on this second tier of wells and then monitor these wells for rate of hydrocarbon recovery to determine the effectiveness of the 1st tier of wells that are now operating.

If we find that hydrocarbon recovery at the 2nd tier of wells continues, then we will install skimmers and possibly additional wells.

We periodically monitor observation wells R-1, R-2, R-3, R-4, R-5, R-6 and R-9 to confirm that hydrocarbon is not migrating toward the ocean.



REV							

CHEVRON U.S.A. INC.

MFG. DEPT. HAWAIIAN REFINERY

DR KPB CH.
DR APP.
ENGR. K BEASLEY
OPR'G. DEPT. APPROVED
ENG'R. DEPT.

SCALE NONE DATE 1-25-87

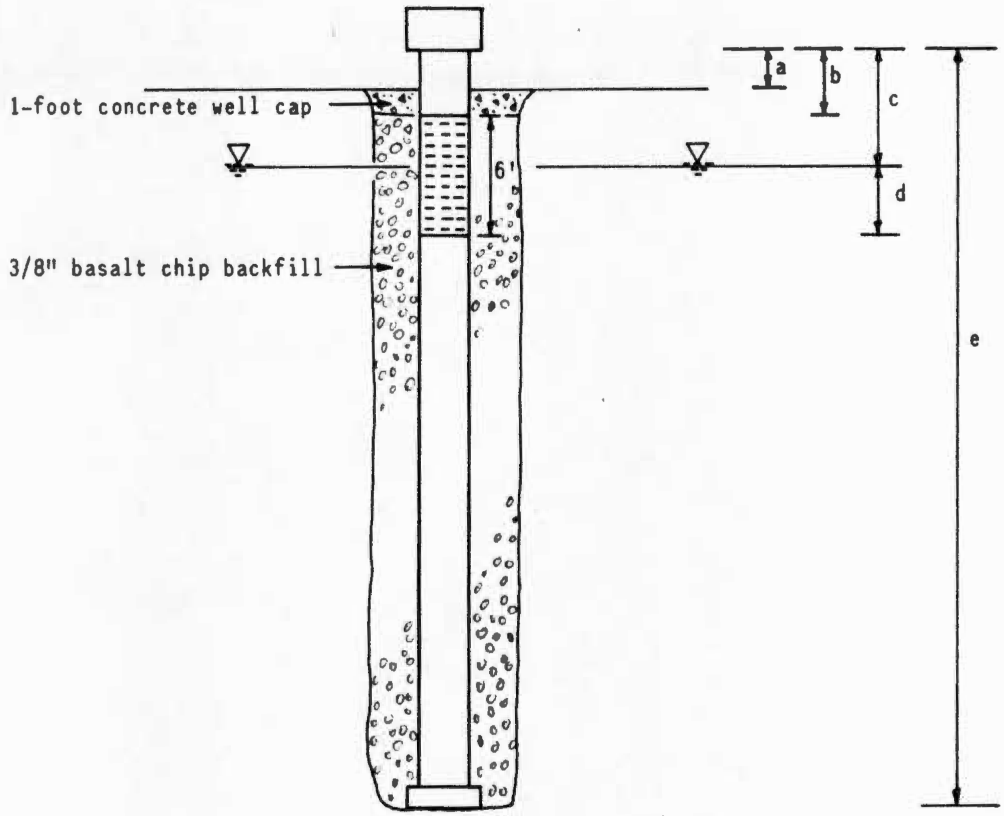
OIL OBSERVATION & RECOVERY WELLS

W.O.
S.O.

SK 10-083

Printed in U.S.A.

GO-580-AB (CD-1-74)



NOT TO SCALE

Where:

a) Stick-up of the PVC pipe from ground surface (feet)

b) Distance from top of PVC to the top of the perforations (feet)

c) Distance from top of PVC to the water level (feet)

d) Distance from the water level to the bottom of the perforations (feet)

e) Total length of the PVC pipe (feet)

NOTE: Subsruface materials generally consisted of tan silty sandy coralline gravel.

WELL CASING DIMENSIONS

FIGURE 1

BY [illegible] DATE 2/17/88 FILE 00113-979-11 REVISIONS BY ____ DATE ____
CHECKED BY ____

DAMES & MOORE

PLATE

SUMMARY OF INDIVIDUAL WELL CASING DIMENSIONS

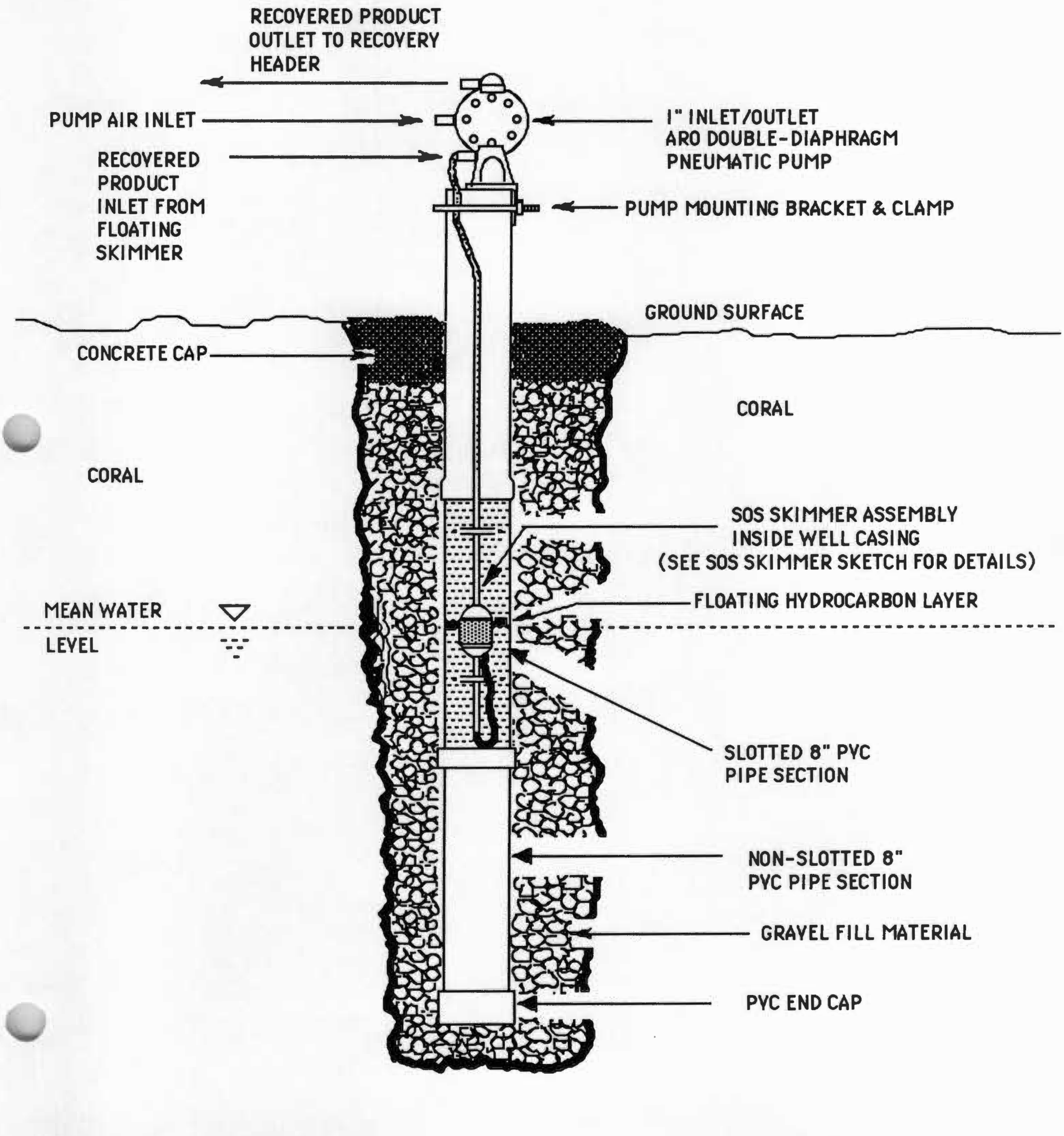
Boring Number	a (ft)	b (ft)	c (ft)	d (ft)	e (ft)	Date Installed
O/R 1	2.8	3.5	5.4	4.1	19.5	01/19/88
O/R 2	2.0	3.0	5.8	3.2	19.2	01/19/88
O/R 3	3.2	3.5	7.3	2.2	19.4	01/19/88
" 4	2.6	3.5	7.0	2.5	19.5	01/19/88
" 5	3.3	3.5	7.7	1.8	20.2	01/19/88
" 6	2.9	3.5	6.1	3.4	19.5	01/20/88
" 7	2.9	3.5	6.4	3.1	17.4	01/20/88
" 8	3.0	3.5	7.0	2.5	16.0	01/20/88

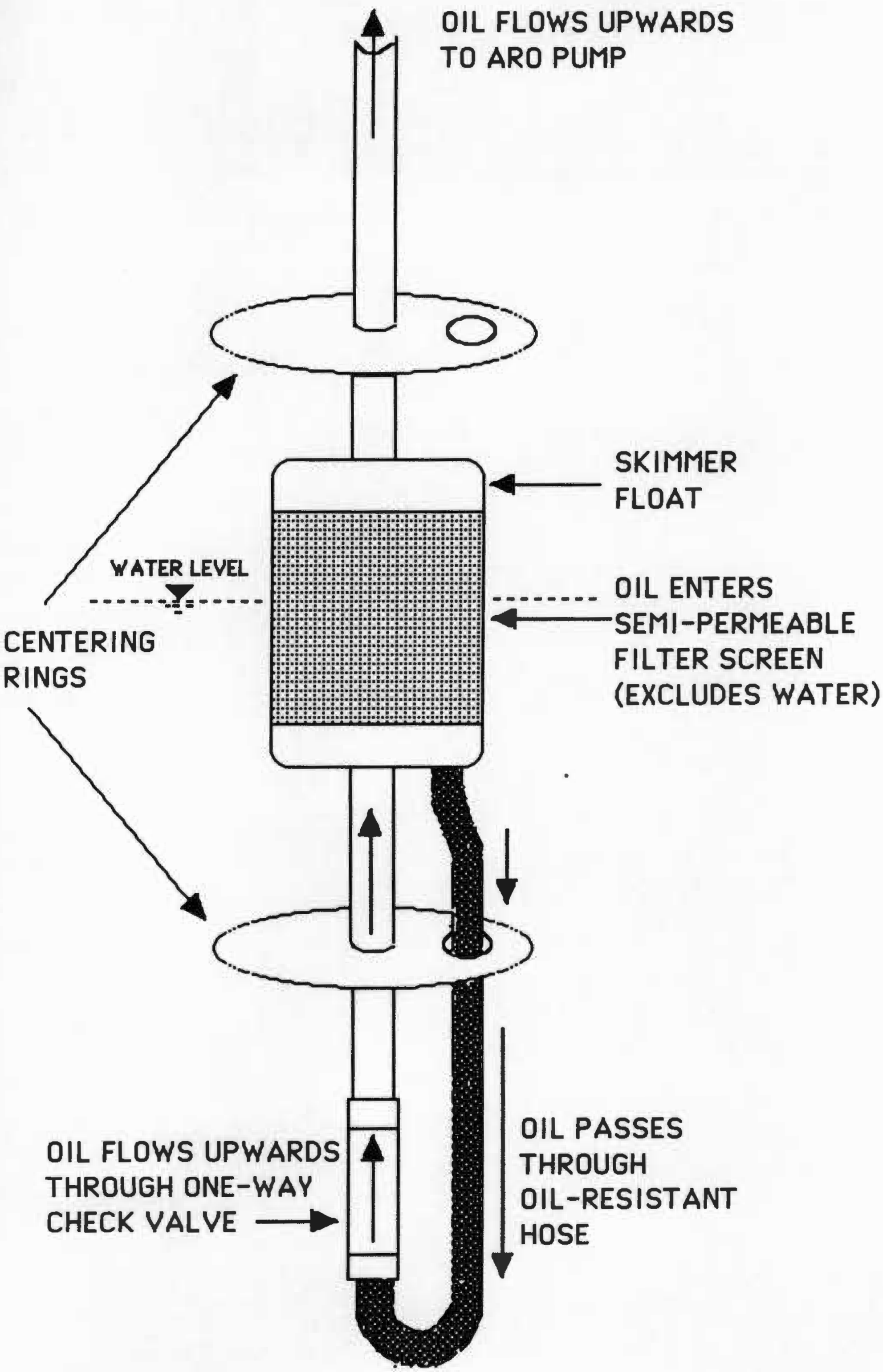
8" OBSERVATION & RECOVERY WELLS ALONG OCEAN COASTLINE ROAD.

FIGURE 2

TYPICAL OIL RECOVERY WELL SETUP

FIGURE 3





SELECTIVE OIL SKIMMER (SOS) DETAILS

FIGURE 4

Section 2. Description of Oily Sewer System and Repairs

The Hawaiian Refinery's Oily Sewer System is comprised of approximately 17,000 linear feet (14,500 linear feet of 4", 6" and 8" diameter pipe and 2,500 linear feet of 10", 12" and 14" diameter pipe) of underground piping. The original underground oily sewer system was constructed of vitrified clay in 1960 when the Refinery was built. (See Drawing 10-HA-1051 for overhead view of Refinery's Oily Sewer System).

Gelco, Inc. was hired in 1988 to clean and TV(video) inspect the entire oily sewer system underlying the Hawaiian Refinery. Low-pressure hydraulic cleaning equipment, high-velocity hydracleaning equipment and mechanical cleaning equipment was used to remove debris such as sludge, dirt, sand, rocks, grease and other solids or semi-solid materials. This debris was trapped and removed at the downstream manholes of the sections being cleaned. All debris was handled and treated in an environmentally acceptable manner.

Following cleaning, visual inspection by means of closed circuit television was performed where infiltration or other defects of the cleaned manhole sections were suspected. The inspection was conducted one section at a time and the section being inspected was suitably isolated from the remainder of the sewer line. A videotaped recording was made to provide a permanent visual and audio record of the manhole sections surveyed.

Phase I of the Oily Sewer System Renovation Project was initiated in 1989 based on findings from the cleaning and inspection portion of the Oily Sewer Renovation Project.

Gelco, Inc. used a patented process known as "Insituform" which provides a structurally sound, corrosion-resistant pipe that is formed within an existing pipe by using a resin-impregnated tube to form the inner lining. Insituform's resin formulation had been selected to meet environmental regulations which require containment of many materials carried by the Refinery's underground oily sewer pipes. This process ensures total containment within the pipeline, preventing exfiltration of contaminants and infiltration of groundwater. Individual sections of insituformed pipe were isolated and subjected to rigid hydrostatic leak testing to ensure a water-tight repair. Each pipe section test sheet was signed by an licensed engineer following completion. The Inspection Test Sheet Log is on file at the Hawaiian Refinery and was not included with this report due to its lengthy format. Refer to Attachment I for a more detailed description of the Insituform process design, its reliability and longevity.

Section 2. Description of Oily Sewer System and Repairs

In addition to use of the Insituform process for renovation, some new concrete catch basins, complete with new lids were installed. Also, all existing floor drain gratings and piping clean out plugs were replaced with new cast iron gratings and plugs. Existing catch basins and manholes were inspected as required. Any voids in the coral discovered during excavations were filled per specification. Finally, all excavations were backfilled and resurfaced.

See Attachment 2 for Contract Specifications for the Oily Sewer System Renovation Project.

ATTACHMENT I

GENERAL INFORMATION

INTRODUCTION

In 1971, Eric Wood, a British engineer, forged a technological breakthrough in sewer and pipeline reconstruction and the first major development in that service industry in decades.

The new pipe repair process was named Insituform, literally meaning "formed in place." The process, brought to the U.S. in 1977, has been used successfully in both municipal and industrial applications, winning the acclaim of engineers for its cost-effectiveness, speed and simplicity of operation and also for its unique ability to reconstruct damaged pipes with a minimum of environmental disruption.

Under the Insituform process, a polyester fiber felt tube, (Insitutube™) is coated on one side with impermeable material and impregnated with a liquid thermosetting resin. This Insitutube, tailored to the exact diameter and length of the damaged pipe, is inverted into the line through an existing manhole or other access point. Cold water in a vertical standpipe forces the Insitutube through the pipe, inverting and pressing it firmly against the existing pipe wall. The water is then heated, curing the resin, and literally creating a new pipe-within-a-pipe, (Insitupipe™).

When first inverted into the fractured pipe, the Insitutube is pliable and the resin is a viscous liquid. It is this characteristic that allows Insituform to fill cracks, push groundwater aside, bridge gaps, and negotiate bends of up to ninety (90) degrees. Using the Insituform process, there is virtually no reduction of pipe size since it molds itself to the contour of the pipe. In fact, combined with its smooth inner surface, it even improves flow capacity. Another major characteristic, particularly valuable in industrial applications, is its ability to resist corrosive chemicals.

The Insituform process is a state-of-the-art technique now serving the pipeline reconstruction needs of customers around the world. Insituform seals, strengthens and preserves municipal and industrial pipelines and appurtenances by building a smooth walled, corrosion resistant Insitupipe.

Insituform of North America, Inc., licensor of the Insituform process in the United States, operates through approved licensees in most major population areas. Headquartered in Memphis, Tennessee, Insituform of North America, Inc., is a publicly held company.

ADVANTAGES OF INSITUFORM

REQUIRES LITTLE, IF ANY EXCAVATION

In most cases Insituform can be installed WITHOUT EXCAVATION by using existing manholes for inversion into the pipeline, thereby eliminating street patches, destruction of surface features, (trees, fences, etc.) and disturbance to other utilities. Service and lateral entries in sewer lines can be opened from the inside of the line by a remote controlled cutter.

TRAVELS THROUGH PIPE — EFFORTLESSLY AND SAFELY

The inversion process effortlessly inverts the impregnated Insitutube inside the existing pipe without friction. The buoyant effect of the water suspends the uninverted Insitutube in a frictionless media, enabling it to traverse long distances between openings. The Insitutube is propelled forward by the weight of water in the inversion standpipe. It snakes itself through misaligned pipe and around bends, pushing water aside. In man-entry pipe sizes it can eliminate the need for workers to enter, thereby doing the same job easier and safer. No other reconstruction method can match the overall ease of application and the versatility of the Insituform process.

FORMS A CONTINUOUS INNER STRUCTURE (A NEW PIPE WITHIN THE OLD)

Insituform bridges over breaks and missing sections of pipe, eliminating infiltration or exfiltration or loss of product (pressure pipe). Insituform fits tightly and can bridge disconnected pipes into a single continuous conduit. The impregnated Insitutube has inherent strength while still in the pliable state; it is installed and cured while under static pressure. Groundwater is locked out the moment Insituform is installed. Its pressure tightness is verified as it is installed and cured. In pipelines with poor alignment, Insituform is the most feasible alternative to total replacement.

FITS UNUSUAL SHAPES AND WIDE RANGE OF SIZES

Insituform fits into unusual shaped conduits, such as elliptical, egg and flat bottom horseshoe cross sections, and has been installed in pipes of various dimensions.

CAUSES ONLY MARGINAL REDUCTION IN DIAMETER

Under the water head used for inversion, the resin impregnated fiber felt Insitutube is held tightly against the inner surface of the pipe so that it is molded to the shape of the pipe; and thereby only a marginal reduction in diameter results.

IMPROVES FLOW

The tight fit minimizes loss of size. The smooth inner surface, absence of joints between openings, and smooth transitions at existing offsets and deflections usually combine to improve flow capacity.

SAVES FUTURE MAINTENANCE

The smooth and continuous inner surface of Insituform reduces deposition because there are no places for deposition to form. In sewers, there are no joints for roots to enter; infiltration is locked out; maintenance is minimal.

BUILDS A CORROSION RESISTANT PIPE

The resin used provides the primary corrosion barrier when cured. A number of thermoset resin systems can be selected to match the corrosive environment. The chemical resistances of two resin systems are listed in Table 2.

BUILDS A PRESSURE PIPE

The thermosetting nature of the resins used yields three-dimensional cross linking: strength in tension, compression, flexural modulus. The thickness can be adjusted over wide ranges, including local thickening over only a portion of the pipeline. The result is a cast-in-place pressure pipe. Few field applied linings can compare in strength.

HANDLES DIFFICULT JOBS

It is possible to install Insituform inside buildings or in pipelines in areas inaccessible to wheeled vehicles. In addition to being applied without excavation, the process has been applied where there is access to only one end, such as vertical wells. It is also possible to reconstruct only a portion of a pipeline or pipelines with reducers.

SAVES TIME AND IMPROVES PUBLIC RELATIONS

Insituform reconstructs pipelines in a fraction of the time of other methods. The convenience of eliminating street excavation (with its disruptions to public access areas, traffic, business and industry), combined with the small work space required, enable Insituform to save time and improve public relations.

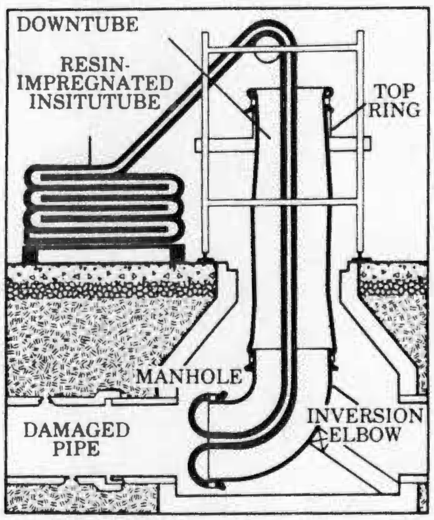
HOW INSITUFORM WORKS

Although state-of-the-art technology, the Insituform process is basically very simple. A needled polyester felt Insitutube is impregnated with a liquid, thermosetting resin and fed into a vertical inversion standpipe which has been erected on-site. The Insitutube has an impermeable coating on the outside which eases handling and provides a water barrier for the inversion process.

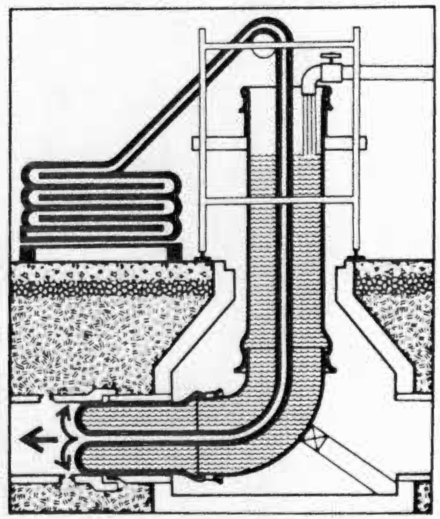
The end of the Insitutube is pulled through the inversion standpipe, turned inside out and securely banded upon the inversion elbow.

Water from nearby hydrants, or other convenient source, is used to fill the inversion standpipe. The force of the column of water pushes the impregnated Insitutube inside-out and into the pipe being reconstructed. As more water is added to maintain a constant force from the vertical standpipe, the Insitutube inverts as it travels through the pipe.

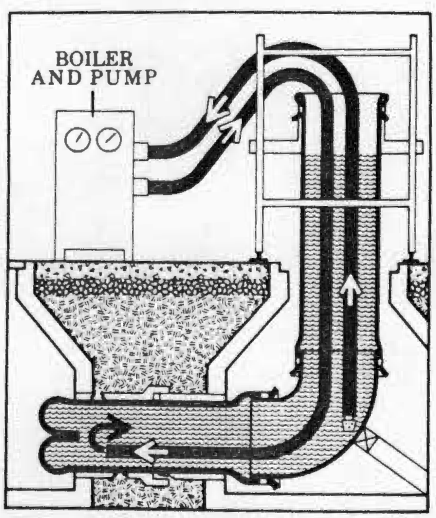
The hydrostatic force presses the coated felt at the nose, inverts it and then presses the resin impregnated side firmly against the inside walls of the damaged pipe. This leaves the smooth impermeable coated side as a new interior surface. After the felt Insitutube reaches the next point of access or becomes fully extended, the water is heated to cure the thermosetting resin and form a new pipe-within-a-pipe, (Insitupipe). The head of water is released, the ends are cut off and the Insituform operation is complete.



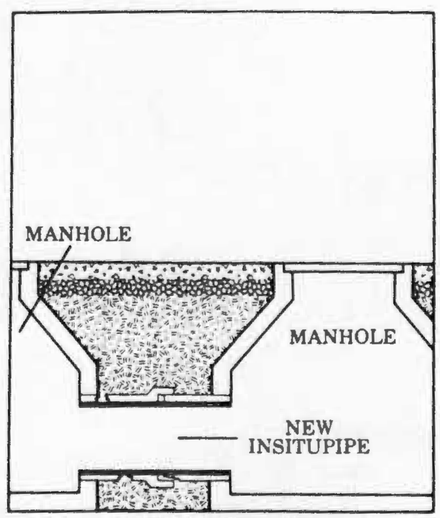
1. The Insitutube is lowered through the downtube and banded to the bottom end of the inversion elbow.



2. When water is added to the downtube its weight pushes the Insitutube through, and tight against, the old pipe.



3. When the Insitutube is fully extended the water is slowly heated, curing it to a rockhard, permanent, pipe-within-a-pipe.



4. After the new Insitupipe has cured and its ends cut flush with the old pipe, it is ready for immediate use.

PHYSICAL PROPERTIES

MATERIALS

Insituform starts as flexible tubes made from one or more layers (depending on desired wall thickness) of polyester felt. An approximate 0.01 inch (0.25mm) polyurethane, polyvinyl chloride, or similar membrane material is bonded to the felt which becomes the outside of the Insitutube. This retains resin in the felt prior to installation. This coating becomes the inside surface when the Insitutube is turned inside out during the inversion process. These coatings are known to have abrasion and chemical resistance properties and can be considered as additional surface protection.

POLYESTER RESINS

The information in Table 1 relates to typical cured Insituform polyester resin composites. Specific data should be obtained for each resin used. The polyester resins used in the Insituform process have seen extensive use in reinforced plastics for more than four decades, both in the manufacture of corrosion resistant tanks and appurtenances in the chemical process industry, and a similar length of service in the manufacture of boat hulls in the fiberglass boat industry.

EPOXY RESINS

Epoxy resins have good adhesion properties and when used in the Insituform process, the new pipe may be bonded to the existing pipe. Epoxies have distinct advantages for gas mains, water mains and product pipelines under pressure.

ADDITIONAL PRODUCT TESTING

Brief summaries of tests performed on Insituform are given in Appendix A. Included are moisture transmission and freeze-heat temperature cycle tests as well as numerous tests by the British Gas Engineering Research Station.

A load test program was instituted to evaluate the structural strength of Insituform in circular conduits. For details, refer to Appendix A of this guide, Insituform of North America, Inc., or its licensees.

TABLE 1

PHYSICAL PROPERTIES — CURED INSITUFORM TYPICAL VALUES

PHYSICAL PROPERTY	POLYESTER*	EPOXY*	UNIT	ASTM
TENSILE PROPERTIES				D-638
TENSILE STRENGTH	3,000	4,000	psi	
FLEXURAL PROPERTIES				D-790
FLEXURAL STRENGTH	4,500	5,000	psi	
FLEXURAL MODULUS RANGE	200,000-300,000	250,000-350,000	psi	
COEFFICIENT OF EXPANSION	6.0×10^{-5}	6.0×10^{-5}	in/in/°C	D-696

*Values shown are for typical polyester & epoxy resins. Specific physical properties should be obtained for each resin used. Polyester classification includes vinyl ester resin.

APPLICATION DATA

TYPICAL INSITUFORM APPLICATIONS

Insituform was developed to provide a means of reconstructing existing pipe, conduit or passageways without extensive excavation. Some typical applications include:

1. Eliminating infiltration or groundwater through joints, breaks and missing sections of gravity pipelines.
2. Eliminating the exfiltration of pollutants and chemicals into the surrounding groundwater aquifer through joints and cracks in pipelines.
3. Halting surface settlement by stopping infiltration of soil and bedding material which often accompanies groundwater infiltration, causing soil voids and shifting ground in gravity pipelines.
4. Increasing the capacity of existing pipelines by smoothing the interior surface and providing smooth transitions over joints and protrusions.
5. Protection of pipelines from attack by corrosive chemical effluents or vapors.
6. Enhancing the strength of soil/pipe systems by curing in place a tight fitting plastic pipe, (Insitupipe) within the old — over joints, cracks and missing pipe and bridging disconnected pipes into a single continuous conduit.
7. Reducing maintenance by eliminating joints and openings for root intrusions into gravity pipelines.
8. Eliminating leaks and strengthening pressure pipeline systems by sealing pinholes, joints or cracks.

SERVICE LIFE

A service life approaching fifty years can be expected for Insituform exposed to normal domestic sewage. This is based on observations of Insituform installed in Great Britain in 1972 which have shown negligible deterioration. Insituform resins have been used extensively in reinforced plastics for over forty years (fiberglass boats, adhesives in aircraft structures, plastic pipe, etc.).

The expected service life of Insituform in pipe applications is a function of the temperature, pressure, velocity and the chemical and abrasive properties of the material being carried.

INFORMATION FOR SELECTION OF INSITUFORM

The factors which must be considered when specifying Insituform for a particular application are as follows:

1. DIAMETER (or perimeter) of the damaged pipeline or conduit.
2. LENGTH of continuous run between manholes or other line access points.
3. WALL THICKNESS required for structural strength.
4. TYPE OF RESIN required for corrosion or temperature resistance.
5. SPECIALS — for pipelines with reducers, local thickening and special requirements.

DIAMETER OF CONDUIT

Any pipeline between 4 inches (102mm) and several feet in diameter can be reconstructed. This would also apply to the circumference of non-circular conduit shapes such as elliptical or rectangular cross-sections.

Insitutubes are, in effect, tailor-made for each installation and it is important that the actual dimensions of the pipelines are specified as closely as possible to ensure a proper fit. In the case of round pipe, the inside diameter should be taken as the average of two or more measurements. For noncircular conduit, the average perimeter should be measured as well as the height-width dimensions.

Conduits with reduction in size between manholes and pipe with numerous bends can be reconstructed; however, overall installation conditions become a factor. Refer such situations to Insituform of North America, Inc. or its licensees prior to specifying.

LENGTH OF CONTINUOUS RUN

The length of continuous run between successive manholes or line access points should be verified by actual measurement. Insituform has been installed in lines up to 2000 feet (610m) in length with standard equipment. Longer continuous insertions are possible depending on the specific job situations, but should be referred to Insituform of North America, Inc. or its licensees prior to specification.

It is not necessary to restrict continuous lengths to each and every access point. Often it is more practical to reconstruct several short sections at one time. This should, however, be the decision of the Insituform installation contractor, unless circumstances require otherwise.

Angles in the conduit of 45 degrees (horizontal or vertical) usually present no problem. Larger angles of bend are possible; a radius of two diameters will accommodate a 90 degree turn with negligible wrinkles or visible surface defects. The locations of the bends need to be taken into account. They are more easily negotiated near the end of a run than at the beginning.

WALL THICKNESS

The wall thickness of Insituform is tailored to the requirements dictated by the design criteria. There are limitations on the thickness and diameter combinations established by practical limitations of the inversion process. The Standard Dimensional Ratio (SDR) is defined as the ratio of the outside diameter divided by the pipe wall thickness. SDR's outside a preferred range may be possible and depend on the specific installation conditions (refer to Insituform of North America, Inc. or its licensees).

RESIN CHEMICAL RESISTANCE

The resin chemical resistance properties for polyester, vinyl ester, and epoxy resins are readily available from Insituform of North America, Inc. and its licensees.

As a general statement, epoxies can develop adhesion to existing pipes whereas polyesters generally do not. Polyesters tend to have slightly better resistance to acids and epoxies to caustics, although this is not always the case. It is best to obtain specific information where the corrosive substance in the effluent can be specifically identified.

All resins have excellent resistance to normal domestic sewage effluents.

Polyester resin is the recommended choice when both cost and corrosion resistance are considered. Where superior corrosion resistance is needed at higher temperatures, vinyl esters are often the logical choice. A wide variety of thermoset resins are potential candidates for the Insituform process and the industry is continually developing more.

For pressure applications where 'tracking' behind the Insituform pipe is of prime importance, epoxies are recommended. Certain residual products, such as phenols, can interfere with the proper curing of polyesters. If the pipeline has residual tar interior linings, samples should be obtained for testing if polyesters are to be considered or a preliner should be considered to avoid direct contact. Refer such questions to Insituform of North America, Inc. or its licensees.

For specific corrosive effluents or atmospheres, or for elevated temperatures and pressures, contact Insituform of North America, Inc. or its licensees prior to Insituform specification.

TABLE 2

RESIN CHEMICAL RESISTANCE

Recommended Temperature Limit — Degrees Fahrenheit °F (°C)

Listed below are a few common compounds including acids, alkaline solutions, bleaches, metal salts and solvents, and the corresponding temperature to which a typical cured polyester or certain vinyl ester products could be subjected under continuous service. A more detailed list is available upon request, as well as resin chemical resistance information for epoxies and other resin systems, which are not available in this format.

Chemical	% Concentration	Temperature °F (°C)	
		Polyester	Vinyl ester
Acetic Acid	10	160 (71)	210 (99)
Acetone	100	N.R.	N.R.
Alcohol, Ethyl	95	78 (25)	100 (38)
Alcohol, Methyl	100	N.R.	70 (21)
Ammonium Chloride	A11	170 (77)	210 (99)
Ammonium Hydroxide	10	N.R.	150 (65)
Ammonium Nitrate	All	N.R.	250 (121)
Benzene	100	N.R.	100 (38)
Calcium Chloride	All	170 (77)	250 (121)
Calcium Hypochlorite	All	120 (48)	180 (82)
Chlorine	Sat'd	75 (28)	210 (99)
Chromic Acid	10	78 (25)	150 (65)
Crude Oil	100	170 (77)	250 (121)
Diesel Fuel	100	150(66)	210 (99)
Ethylene Glycol	100	150 (66)	210 (99)
Ferric Chloride	All	170 (77)	210 (99)
Gasoline, Leaded	100	150 (66)	180 (82)
Gasoline, Unleaded	100	78 (25)	150 (65)
Hydrochloric Acid	10	160 (71)	230 (110)
Jet Fuel (JP-4)	100	78 (25)	180 (82)
Magnesium Sulfate	All	170 (77)	250 (121)
Methyl Ethyl Ketone	100	N.R.	70 (21)
Nitric Acid	10	N.R.	170 (77)
Phosphoric Acid	85	170 (77)	210 (99)
Potassium Chloride	All	170 (77)	210 (99)
Potassium Nitrate	All	170 (77)	210 (99)
Potassium Permanganate	All	78 (25)	210 (99)
Sodium Hydroxide	25	N.R.	180 (82)
Sodium Hypochlorite	18	N.R.	160 (71)
Sodium Silicate	All	N.R.	210 (99)
Sulfuric Acid	25	170 (77)	210 (99)
Stannic Chloride	All	170 (77)	210 (99)
Trichloroacetic Acid	50	80 (27)	210 (99)
Toluene	100	78 (25)	120 (49)
Trisodium Phosphate	All	N.R.	250 (121)
Turpentine	100	78 (25)	210 (99)
Urea	50	120(49)	150 (66)

N.R. = Not Recommended

FLOW CHARACTERISTICS

GRAVITY FLOW

The flow characteristics of Insituform depend on the condition of the existing line. In gravity sewer lines, the factors which determine flow velocities and hence total capacity include:

1. Surface roughness of the conduit material (erosion, major irregularities in the pipe, offset joints, deposits, or partially removed coatings).
2. Horizontal alignment and vertical grade.
3. Presence of protrusions into the line such as poor lateral service connections.

Insituform will generally improve the above factors. An increase of flow capacity can be expected due to smooth transitions at offsets and protrusions, no joints between manholes, and a smooth inside surface. Manning coefficient (n) value of 0.009 can be expected in reasonably straight lines with constant grade.

The smoothness also improves capacity by reducing deposition. Because open joints and misalignments are improved, there are fewer places for deposition to form. The continuous nature of the new pipe within the old keeps debris moving, increasing capacity and reducing maintenance.

The traditional Manning equation can be used to determine specific flowrates assuming full-flow gravity lines.

$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2} \qquad (\text{ft}^3/\text{sec})$$

A = Flow area of pipe (ft^2)

n = Manning coefficient

R = hydraulic radius (ft) = $D/4$ for circular pipe
where D = pipe internal diameter (ft)

S = slope (feet/foot)

For circular pipe, the formula may be simplified to:

$$Q = \frac{0.463\, D^{8/3} S^{1/2}}{n} \qquad (\text{ft}^3/\text{sec})$$

For comparison of an existing pipe after Insituform to the previous flow capacity, this formula can be simplified as follows:

$$\%\ \text{New Flow Capacity} = \frac{n_{\text{existing}}}{n_{\text{Insituform}}} \left[\frac{D_{\text{Insituform}}}{D_{\text{existing}}}\right]^{8/3} \times 100$$

Example: 1

Determine the percent new flow capacity for a 12 inch diameter reinforced concrete pipe reconstructed with a 0.25 inch thick Insitutube.

$n_{\text{RCP}} = 0.015$ Reference: *Wastewater Engineering, Collection, Treatment, Disposal*; by Metcalf and Eddy

$n_{\text{Insitu}} = 0.009$

$D_{\text{RCP}} = 12''$

$D_{\text{Insitu}} = 12'' - 2(0.25'') = 11.5''$

$$\%\ \text{New Flow Capacity} = \frac{0.015}{0.009} \left[\frac{11.5}{12.0}\right]^{8/3} \times 100$$

$$= 149\%$$

Table 3 illustrates the increased flow capacity after Insituform with respect to pipe material and various Standard Dimensional Ratios (SDR).

TABLE 3

PERCENT OF FLOW CAPACITY TO BE EXPECTED FROM VARIOUS PIPE MATERIALS AFTER INSITUFORM OF VARIOUS SDR'S COMPARED WITH EXISTING PIPES (100%).

		SDR			
PIPE MATERIAL AND 'n' VALUE		**30**	**40**	**50**	**60**
CLAY PIPE	n = 0.013	120%	126%	130%	132%
CONCRETE PIPE	n = 0.015	139%	145%	149%	152%

PRESSURE FLOW

Insituform in pressure flow applications enhances the existing pipe characteristics in the same manner as stated in the gravity flow section. The reconstructed pipe without joints, protrusions, offsets and a greater Hazen-Williams smoothness coefficient promotes a more laminar flow. Insituform generally improves the flow capacity of existing pipes.

The Hazen-Williams (H-W) equation can be used to compute the specific flowrate of each pipe.

$$Q = 1.318\ C\ R^{0.63}\ S^{0.54}\ A \qquad (ft^3/sec)$$

Where Q = flow in CFS

C = H-W smoothness coefficient, for Insituform, a C value of 140, or the same as plastic pipe, is commonly used.

R = hydraulic radius; flow area divided by the wetted perimeter

S = slope (feet/foot)

A = flow area in square feet

For circular pipes, the H-W equation can be modified as follows:

$$Q = 0.432\ C\ D^{2.63}\ S^{0.54} \qquad (ft^3/sec)$$

To compare the Insituform flowrate to that of the existing pipe, the H-W equations reduce as follows:

$$\%\ \text{New Flow Capacity} = \frac{C_{Insitu}}{C_{exist}} \left[\frac{D_{Insitu}}{D_{exist}}\right]^{2.63} \times 100$$

Example: 2

Determine the % new flow capacity for an 18 inch diameter, old riveted steel pipe with a 0.30 inch thick Insituform.

The value for the H-W smoothness coefficient of an old riveted steel pipe is C = 95 (Reference — *Wastewater Engineering, Collection, Treatment, Disposal*; Metcalf and Eddy).

$$\%\ \text{New Flow} = \frac{140}{95} \left[\frac{18 - 2(0.3)}{18}\right]^{2.63} \times 100$$

$$= 135\%$$

Table 4 illustrates the increased flow capacity of various pipe materials after Insituform reconstruction.

TABLE 4

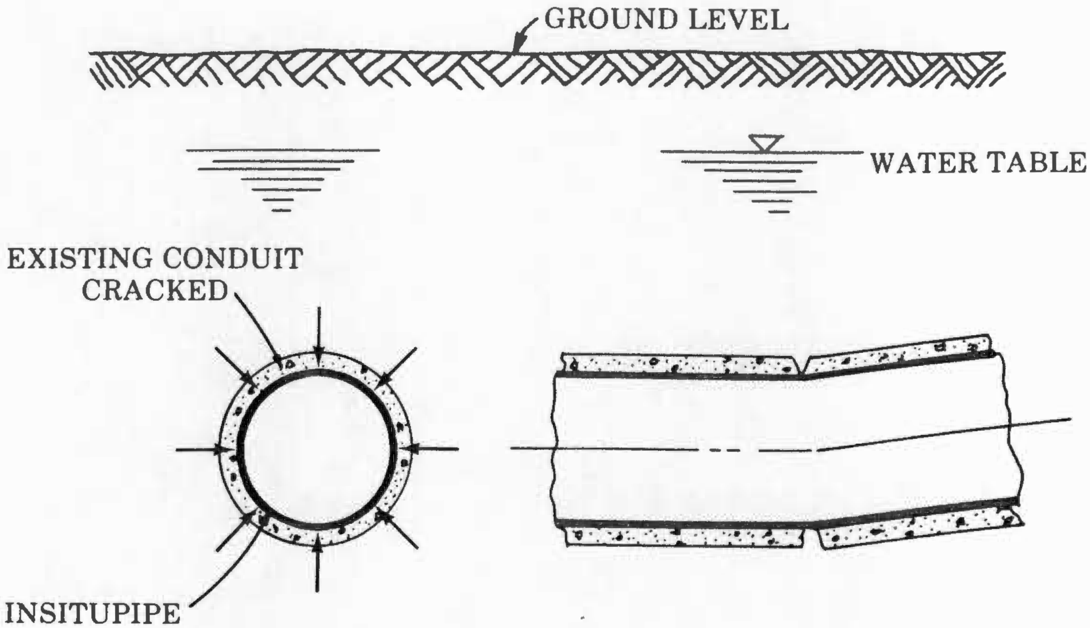
PERCENT OF FLOW CAPACITY TO BE EXPECTED FROM VARIOUS PIPE MATERIALS AFTER INSITUFORM (EXISTING PIPE 100%)

	D_{Insitu}/D_{exist}			
PIPE MATERIAL AND C VALUE	**0.97**	**0.95**	**0.93**	**0.91**
Old cast iron; C = 100	129	122	116	109
Old riveted steel; C = 95	136	129	122	115
Old cast iron; C = 70 (in bad condition)	185	175	165	156

ABRASION

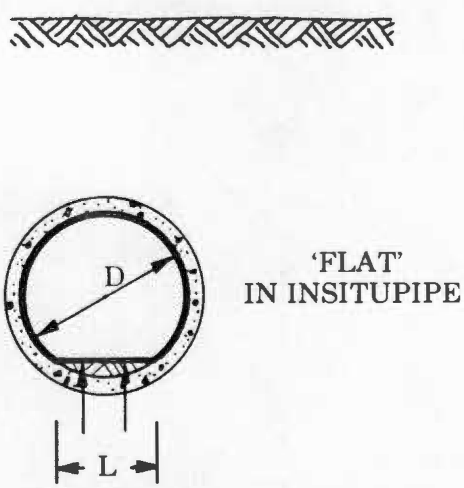
Insituform resists the effects of slurries and abrasives in a number of ways. The plastic nature of the materials is well known for abrasion resistance, often outlasting mild steel several times over. Secondly, the polyurethane coating, which becomes the inner surface, has been proven to be a tough elastomer and a barrier to abrasion. Thirdly, it is generally known that turbulence increases the effect of abrasion. Surface roughness, offset joints, fractured pipe or any interior protrusion will cause turbulence. Abrasion is reduced because Insituform virtually eliminates joints and smoothes over such protrusions and thereby achieves a more laminar flow. Sections of pipelines of approximately 2000 ft. (610m) in length have been formed into a single jointless pipe by the Insituform process.

DESIGN CONSIDERATIONS FOR GRAVITY (OPEN CHANNEL) PIPELINES SUBJECTED TO EXTERNAL SOIL AND HYDROSTATIC PRESSURES



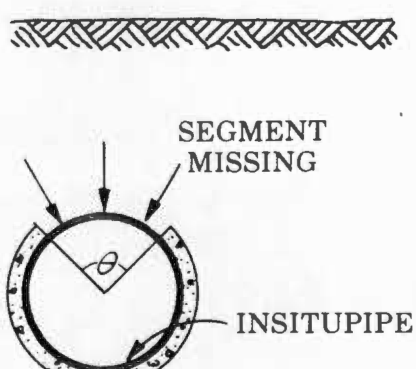
CIRCULAR CONDUIT — CRACKED & LEAKING BUT OFFERING FIRM SIDE SUPPORT TO INSITUFORM (USE CHART 1 & TABLES 7 & 7A)

PIPE DEFORMED CIRCULAR SECTION WITH FLAT PORTION



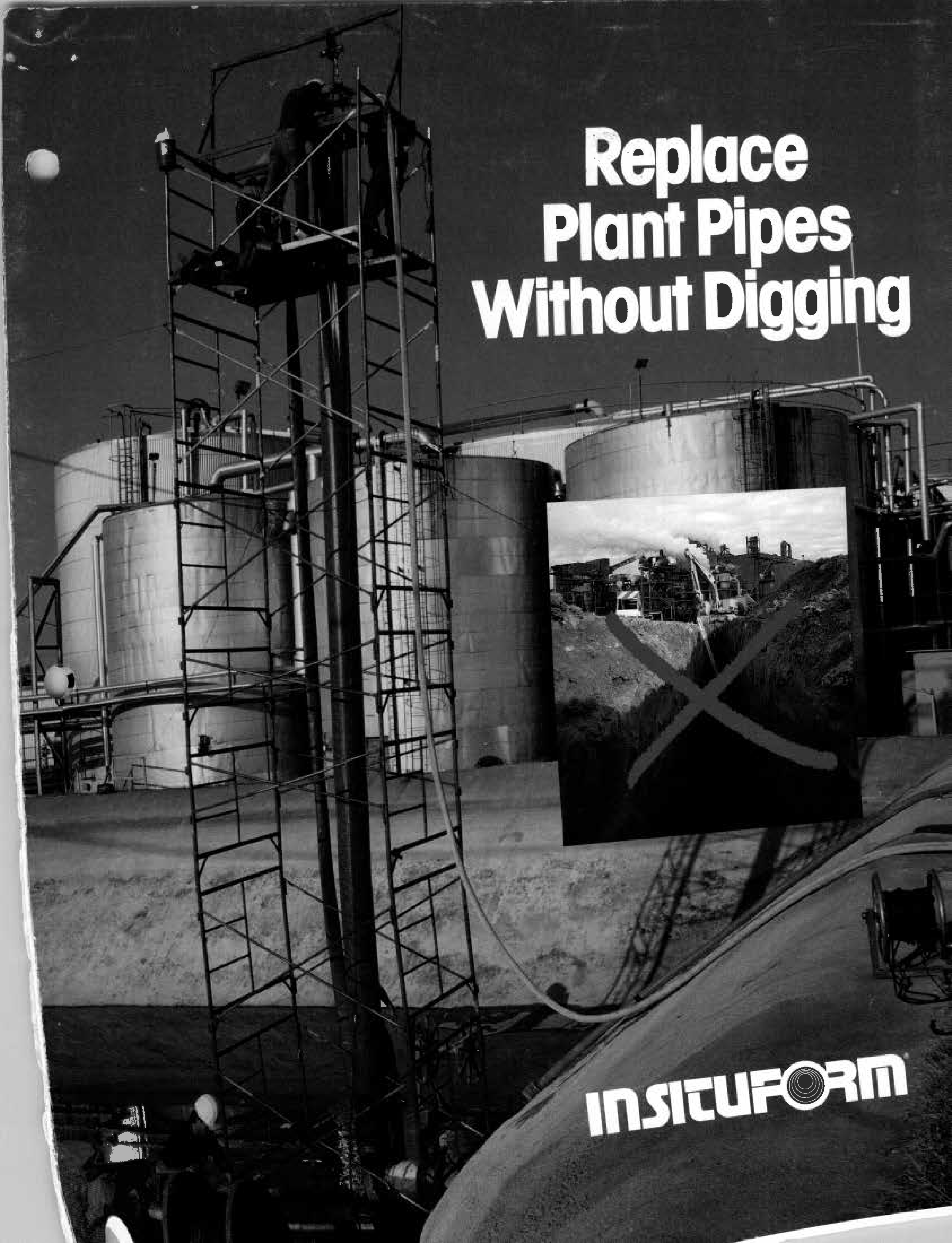
USE CHART 2 & TABLES 8 & 8A

PIPE SEVERELY DAMAGED — SEGMENT MISSING



USE CHART 3 & TABLE 9

Replace Plant Pipes Without Digging



INSITUFORM

III. SPECIFICATION FOR INSITUPIPE RECONSTRUCTION

1. GENERAL INSITUPIPE REQUIREMENTS

1.1 The new pipe shall be an "Insitupipe", resin-impregnated polyester fiber felt tubing, lined on one side with polyurethane and fully impregnated with a liquid epoxy thermosetting resin. The cured material shall conform to the following minimum structural standards:

Test	Standard	Min. Results
Tensile Stress	ASTM D-638	3,000 psi
Flexural Stress	ASTM D-790	4,500 psi
Modulus of Elasticity	ASTM D-790	250,000 psi

Finished pipe to have a minimum of 100 percent of original flow.

1.2 Required Insitupipe Size

The Insitupipe for sewer pipe 4, 6, 8, 10, 12, and 14-inches nominal diameter shall be a nominal 3, 4.5, 6, 6, 7.5, and 9 millimeters thick respectively.

2. GENERAL PRE-INSTALLATION REQUIREMENTS

The following pre-installation requirements shall be adhered to by the CONTRACTOR, unless otherwise approved:

2.1 Inspection and Cleaning

CONTRACTOR shall perform television inspection both before and after cleaning each pipeline so that the COMPANY REPRESENTATIVE can view the televised video tapes prior to pipe cleaning and repair operations. Prior to any Insituforming of a designated pipeline, it shall be the responsibility of the CONTRACTOR to clean and clear the pipeline of obstructions, such as solids, or roots that will prevent the insertion of the Insitupipe. Pipeline cleaning shall be done with an approved method acceptable to the COMPANY. If inspection reveals an obstruction that cannot be removed by conventional cleaning equipment, then the CONTRACTOR shall make a pipe repair excavation to uncover and remove or repair the obstruction. The CONTRACTOR shall notify the COMPANY REPRESENTATIVE prior to each such inspection, permit the COMPANY REPRESENTATIVE to view the inspection and shall obtain the COMPANY REPRESENTATIVE's approval before to proceeding with the Insitupipe installation.

All oily sludge removed from the system may be disposed of in the COMPANY's Landfarm holding pit once it has passed a paint filter test. All oily water (strained of all sediment) may be disposed of in the Blending and Shipping Area Oily Drainage Sump.

2.2 Video Inspection

The CONTRACTOR's inspection of the pipelines shall be performed by experienced personnel trained in locating breaks, obstacles, and service connections by closed-circuit television. The interior of the pipeline shall be carefully inspected to determine the location and extent of any structural failures. The locations of any condition which may prevent proper installation of Insitupipe into the pipelines shall be noted so that these conditions can be corrected. A video tape and suitable log shall be dept for later reference by all parties.

The COMPANY shall provide existing plans and estimated quantity of flow in gallons per minute to the CONTRACTOR for the planning of transferral operations.

2.3 Cleaning and Video Inspection Detailed Specifications

Detailed specifications for the cleaning and video inspection work to be performed are given in Exhibit - Specification for Cleaning And Internal Video Inspection of the Oily Water Drainage System.

2.4 By-passing Sewer Flow (Transfer of Existing Flows)

Where required, CONTRACTOR shall provide for the transfer of effluent flow around the section or section of pipe that are to Insituformed. The bypass shall be made for diversion of the flow at an existing upstream access point and pumping the flow into a downstream access point of adjacent system. The pump and bypass lines shall be of adequate capacity and size to handle the flow. The effluent flow height shall not exceed on foot above the crown of any active sewer pipe access point. CONTRACTOR shall immediately repair any leaks in the bypass piping.

The bypass pumping should be scheduled for 24-hour continuous duty from the start of the operation with backup equipment available for periods of maintenance and refueling.

3. INSTALLATION REQUIREMENTS

3.1 CONTRACTOR shall designate a location where the uncured resin in the original containers and the un-impregnated Insitupipe will be vacuum impregnated prior to installation. CONTRACTOR shall allow the COMPANY to inspect the materials and the "wet-out" procedure. A resin and catalyst system compatible with the liquid thermosetting materials shall be per INS manufacturer's standards to provide the nominal Insitupipe thickness specified.

3.2 Insitupipe Insertion

The wet-out Insitupipe shall be inserted through an existing manhole or other approved access by means of an inversion process and the application of hydrostatic head sufficient to fully extend the Insitutube to the next designated access point. The impregnated Insitutube shall be inserted into the inversion tube with the impermeable plastic membrane side out. At the lower end of the inversion tube, the Insitutube shall be turned inside out and attached to the inversion tube so that a leak proof seal is created. The inversion head will be adjusted to be sufficient height to invert the Insitutube to the next access point designated and to hold the Insitupipe snug to the pipe wall and to produce dimples at side connections and flared ends at the entrance and exit access points. The use of a lubricant is recommended and, if used, such lubricant shall be as approved by INA manufacturer's standard. The INA manufacturer's standards shall be closely followed during the elevated curing temperature so as not to over stress the Insitutube and cause damage or failure of the Insitutube prior to cure. In certain cases, CONTRACTOR may elect to use a Top Inversion. In the Top Inversion method, the Insitutube is pre-inverted to a distance that corresponds to the minimum inversion head and instead of attaching to an elbow at the base of the inversion tube, the Insitutube is attached to a top ring.

When required, the inversion may be an air or pull-in type inversion.

3.3 Insitupipe Curing

After inversion is completed, CONTRACTOR shall supply a suitable heat source and water recirculation equipment. The equipment shall be capable of delivering hot water to the far end of the Insitupipe through a hose, per INA manufacturer's recommendations, to uniformly raise the water temperature in the entire Insitutube above the temperature required to effect a cure of the resin. The curing temperature and the length of the cure shall be determined by the manufacturers instructions for the resin/catalyst system employed. The inversion may be steam cured when required.

The heat source shall be fitted with suitable monitors to gauge the temperature of the incoming and outgoing heat exchanger circulating water. Thermocouples shall be placed between the Insitupipe and the invert at near and far access to determine the temperature of the Insitupipe and time of exotherm. Water temperature in the line during cure period shall not be less than 150°F or more than 200°F as measured at the heat exchanger return line.

Initial cure shall be deemed to be completed when inspection of the exposed portions of the Insitupipe appear to be hard and sound and the thermocouples indicated that an exotherm has occurred. The cure period shall be of a duration recommended by the resin manufacturer, as modified for the Insituform process, during which time the recirculation of the water and cycling of the heat exchanger to maintain the temperature in the Insitupipe continues.

3.4 Cool-Down

CONTRACTOR shall cool the hardened Insitupipe to a temperature below 100°F before relieving the static head in the inversion tube. Cool down may be accomplished by the introduction of cool water into the inversion tube to replace water being drained from a small hole made in the end of the Insitupipe at the downstream end. Care shall be taken in the release of the static head such that a vacuum will not be developed that could damage the newly installed Insitupipe.

3.5 Finished Insitupipe

The finished Insitupipe shall be continuous over the entire length of an inversion and be as free as commercially practicable from visual defects such as foreign inclusions, dry spots, pinholes, and delamination. The Insitupipe shall be impervious and free of any leakage from the pipe to the surrounding ground to the inside of the Insitupipe.

Any defects which will affect, in the foreseeable future or warranty period the integrity or strength of the Insitupipe shall be repaired at the CONTRACTOR's expense in a manner mutually agreed upon by the COMPANY and the CONTRACTOR.

3.6 Sealing Insitupipe at the Ends

If due to broken or misaligned pipe at the access point, the Insitupipe fails to make a water tight seal, the CONTRACTOR shall apply a seal at the point. The seal shall be of a resin mixture compatible with the Insitupipe. Any contaminated concrete or pipe shall be removed such that the resin is applied to a bondable surface.

3.7 Side Sewer Service Reinstatement

After the Insitupipe has cured, the CONTRACTOR shall reinstate the existing active side sewer connections as designated by the COMPANY REPRESENTATIVE and/or shown on the plans. This shall generally be done without excavation and from the interior of the pipeline by means of a cutting device that re-establishes them to not less than 90 percent capacity.

3.8 Insitupipe Testing

The water tightness of the Insitupipe may be gauged while the Insitutube is curing and under positive head. The final watertightness test (for COMPANY acceptance) shall be made after all cuts, lateral reinstatements and end seals have been made.

All final video inspections shall be reviewed and approved by the COMPANY. CONTRACTOR shall bear all costs incurred in correcting any deficiencies found during the final watertightness test and/or video inspection.

4. MEASUREMENT

Measurement for Insitupipes shall be the linear distance between manhole centers as measured along the center line of the pipe. Measurement for depth shall be from the pipe invert to the surface.

Measurement for Insitupipes material will be by the linear foot and wall thickness for each size of Insitupipe. Measurement for all other work shall be by each, lineal foot, or lump sum.

THIS PAGE ENDS SECTION III - SPECIFICATION FOR INSITUPIPE RECONSTRUCTION